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ABSTRACT

Introspection is a technique which can be used to explore memory. For this study, two questions were posed: (1) do students who better retain previously learned intellectual skills and propositions report a greater number of links between and within Gagne and White's four memory structures (networks of propositions, intellectual skills, images, and episodes)? and (2) what types of of links are reported by students, and what is the relationship with instruction? Seventy-eight high school chemistry students received instruction on Boyle's Law and Charles' Law; Two days (retention I and 6 weeks (retention II) after completion of instruction, the same retention test was administered individually to all students. After answering each question, the student was asked about thoughts and/or pictures which flashed through his or her mind while deciding how to answer. Student responses were taped, transcribed, and coded. From the codings, the number of reported links between and within the four types of memory structure was calculated and compared to performance on the retention test. Students who better retained previously learned propositions and intellectual skills generally reported a greater number of links between and within the four memory structures. (BW)

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INTROSPECTION AS A TECHNIQUE FOR INVESTIGATING RETENTION

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Victoria College: A College of Advanced Education

June 1982

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Educators pay much attention to instructional processes and student performance. They tend, however, to ignore the intervening stage of memory. With an understanding of how memory works, instruction can be based on a set of principles rather than on intuition, guesswork, or trial and error.

Psychologists have used various techniques to explore memory. Introspection is one such technique which is highly regarded by some (Bloom and Broder, 1950; Burt, 1962; Radford, 1964) and criticised by others (Watson, 1963; Hollenberg, 1970). In some introspection studies (Duncker, 1945; Bloom and Broder, 1950; De Groot, 1966) individuals have been asked to 'think aloud' while carrying out a task, while in others (Neimark, Slotnick and Ulrich, 1971; Marton and Säljö, 1976; Pines, 1977; Hewson, 1980) they have been asked to report on certain aspects of memory following an event. Subjects' comments are often tape-recorded. Various strategies are used to code the protocols, present the resulting data and make inferences concerning cognitive processes.

Education is most concerned with long term memory. Morton (1975) considers that long term memory can better be understood in terms of its divisions rather than as a single system. In considering long term memory, Bruner (1969) distinguishes between 'memory with record' and 'memory without record'. Tulving (1972) proposes semantic and episodic memory stores or systems; Paivio (1975a, b) suggests verbal and non-verbal (imagery) cognitive systems. Gagné and White (1978) postulate four kinds of organised memory structures: networks of propositions, intellectual skills, images and episodes. They claim that a student's understanding is enhanced the greater the number of links between and within these long term memory structures.

For this study the following questions were posed -

- Do students who better retain previously learned intellectual skills and propositions report a greater number of links between and within the four memory structures proposed by Gagné and White?

- What types of links are reported by students, and what is the relationship with instruction?

Various strategies were developed to present the data.

METHOD

The Gas Laws is a topic usually covered in a beginning chemistry course. Students are expected to be able to calculate the volume of a given mass of gas at a new temperature and pressure. Defining this as the superior skill, a hierarchy of intellectual skills was developed and to this hierarchy were linked many propositions and other intellectual skills. Based on this information five instructional booklets were prepared in which were incorporated two practical experiments on Boyle's Law and Charles' Law.

The sample comprised seventy-eight students from four Year 10 chemistry classes in the same suburban high school. These unstreamed classes were taught by two teachers each with at least five years science teaching experience. The class teachers were responsible for administering the prescribed instruction which covered a three week period.

Two days (retention I) and six weeks (retention II) after completion of instruction, the same Retention Test (Appendix A) was administered individually to all students. After a student wrote down the answer to each of the eight intellectual skill questions and six proposition questions, the interviewer asked "Now, what thoughts and/or pictures flashed through your mind while you were deciding how to answer the question?" The oral responses were tape recorded.

RESULTS

Coding of the protocols

Protocols of the interviews at both retention I and retention II were transcribed. At retention I ten protocols were considered in detail and used to develop an initial coding scheme which was based on the four types of memory structure: propositions (P), intellectual skills (S), images (I), episodes (E). Within these main coding categories were a number of items: P_1-P_6, P_s; S_1-S_4, S_s; I_1; E_1-E_{17}, E_s. Students' comments not falling into these four main categories were coded in category X: X_1-X_6. The remaining protocols were coded using this scheme. Very few additional coding items were required to be added to the initial coding scheme to cover all responses. Examples of codings are provided.

- I am imagining a gas syringe with oxygen in it - just pictured it in my mind. I just saw it./ I can't think./ (Q.7, no written answer) — Coded I_1X_1
- Um. I just remembered the tests we've been doing in class in the Books./ (Q.1, correct answer) — Coded E_1S_1
- Nothing really. Just - I thought of it and wrote it down./ (Q.13, correct answer) — Coded P_1

The final coding scheme is shown in Table 1

To illustrate the type of results obtained, the coding of the first question in the Retention Test is given in Table 2. From the table it is noted, for example, that student No. 13 simply reported using the appropriate intellectual skill at retention I (S_1), but at retention II there was a reported link to an episode relating to the Booklets (E_1), a search for a proposition (P_s), and then a link to the appropriate intellectual skill (S_1). Performance was correct at both retentions I and II. However for student No. 27 there was incorrect performance at both retention stages. At retention I there was the reported proposition link 'add 273' (P_4) followed by a partly correct link to the intellectual skill (S_2), while at retention II the link to the intellectual skill was completely incorrect (S_3). For each question in the Retention Test protocol data were analysed as represented by Table 2.

Table 1: Coding Scheme used with Student Protocols

Episode reported relating to

E_1 the Booklets
E_2 the teacher during the science sessions
E_3 the work done in science
E_4 the mathematics class
E_5 other than the science or mathematics classes
E_6 Charles' Law experiment
E_7 incidents during Charles' Law experiment
E_8 Boyle's Law experiment
E_9 incidents during Boyle's Law experiment
E_{10} having done the work in class but couldn't remember it
E_{11} having done the work before but did not actually understand it at the time
E_{14} the question being in the last interview
E_{15} the question being in the last interview and the same answer being given
E_{16} the question being in the last interview and couldn't be answered then
E_{17} the question being in the last interview and couldn't be answered then but the answer to the question being subsequently found

Episode inferred from a statement relating to

E_{12} seeing the question and knowing immediately it couldn't be answered
E_{13} having not actually done the work in class

Proposition reported was

P_1 correct
P_2 partly correct
P_3 incorrect
P_4 add 273
P_5 subtract 273
P_6 choose from two or more propositions

Image produced

I_1 from the question

Intellectual skill carried out was

S_1 correct
S_2 partly correct
S_3 incorrect
S_4 relating a question to another question in the test

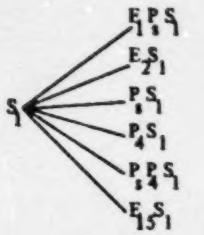
A search was indicated for

E_s any episode that could relate to the question
S_s the methodology of the intellectual skill
P_s a proposition

Other aspects reported

X_1 don't know/can't remember
X_2 not sure
X_3 guessed
X_4 hard/harder than
X_4 easy/easier than
X_6 worried

Table 2: Coding of Protocols for Retention Test Q.1

Retention I	Retention II	Student Number
A. Student correct retentions I, II		
		13
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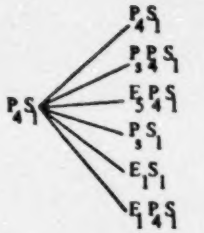		23, 28, 45, 52, 56, 68
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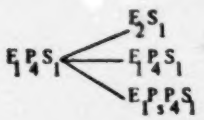		33
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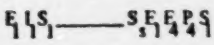		21
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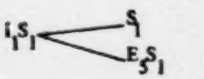		78
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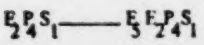
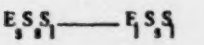
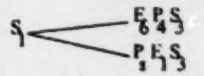
		57
		67
B. Student correct retention I, incorrect retention II		
		51
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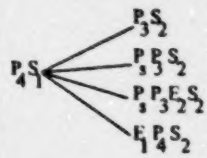		29
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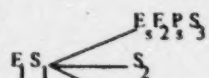		58
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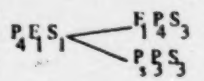		06
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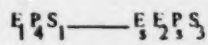
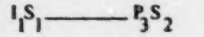
		14
		22
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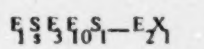
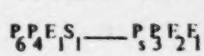
		09
		43
C. Student incorrect retention I, correct retention II		
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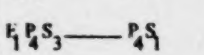
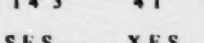
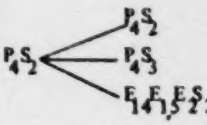
		37
		63
		40
		11
		79
		46
		76
D. Student incorrect, retentions I, II		
		17
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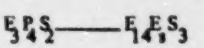
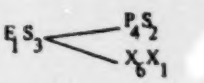
		01
		36
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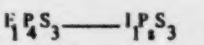
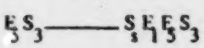
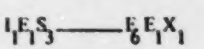
		34
		30
		44
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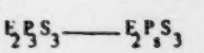
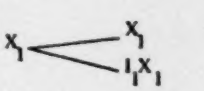
		05
		07
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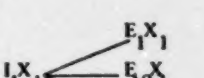		25
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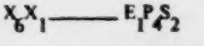		07

Intellectual Skills

From the codings of the interview data, the number of reported links between and within the four types of memory structure was calculated for each intellectual skill question at both retention I and retention II. This figure was compared with Retention Test performance in which each question was scored either correct (✓) or incorrect (x). To indicate the method used to present this data, responses to questions 1 and 3 are given.

Table 3: Number of Students Reporting a Certain Number of Links, and Mean Number of Links, Between and Within the Four Memory Structures for the Intellectual Skill Questions 1 and 3 in the Retention I and II Tests

		Number of links reported								
		0	1	2	3	4	5	Mean	S.D.	
Retention I	Q.1 ✓		8	27	13	1	1	2.20	0.81	*
	x	3	6	12	7			1.75	0.93	
	Q.3 ✓		13	15	10		1	1.92	0.78	
	x	1	15	17	5		1	1.74	0.82	
Retention II	Q.1 ✓		1	26	10	4	1	2.48	0.80	
	x	3	5	9	14	4	1	2.39	1.20	
	Q.3 ✓		6	18	6	2		2.12	0.79	
	x	3	5	26	10	2		2.07	0.88	

Note: * $p<.05$; ** $p<.01$

Only for questions 1(I) and 4(II) were there significant differences between means.

From the protocols, similarities in the linking patterns are noted. To summarise a further dimension of the interview data the main patterns of linking were determined for each question and represented both in table and diagrammatic form. There is some loss of data in adopting this strategy, but it does enable main linking patterns to be highlighted.

Table 4: Number of Students Reporting Particular Patterns of Linking for the Intellectual Skill Questions 1 and 3 at Retentions I and II

Main patterns of linking reported from student interviews		Q.1				Q.3			
		Retention I		Retention II		Retention I		Retention II	
		Student Performance ✓	x	✓	x	✓	x	✓	x
. just did it	(S)	8	1	2	1	12	5	5	3
. episode Booklets and did it	(ES)	6	5	4	1	2	3	1	1
. episode Booklets and add 273 and did it	(EPS/ PES)	8	3	2	2	1	-	-	-
. add 273 and did it	(PS)	16	4	12	3	3	10	7	1
. related Q. to another Q. in Test and did it	(SS)	-	-	-	-	5	1	5	6
Overall, patterns of linking quite varied		no		yes		yes		yes	

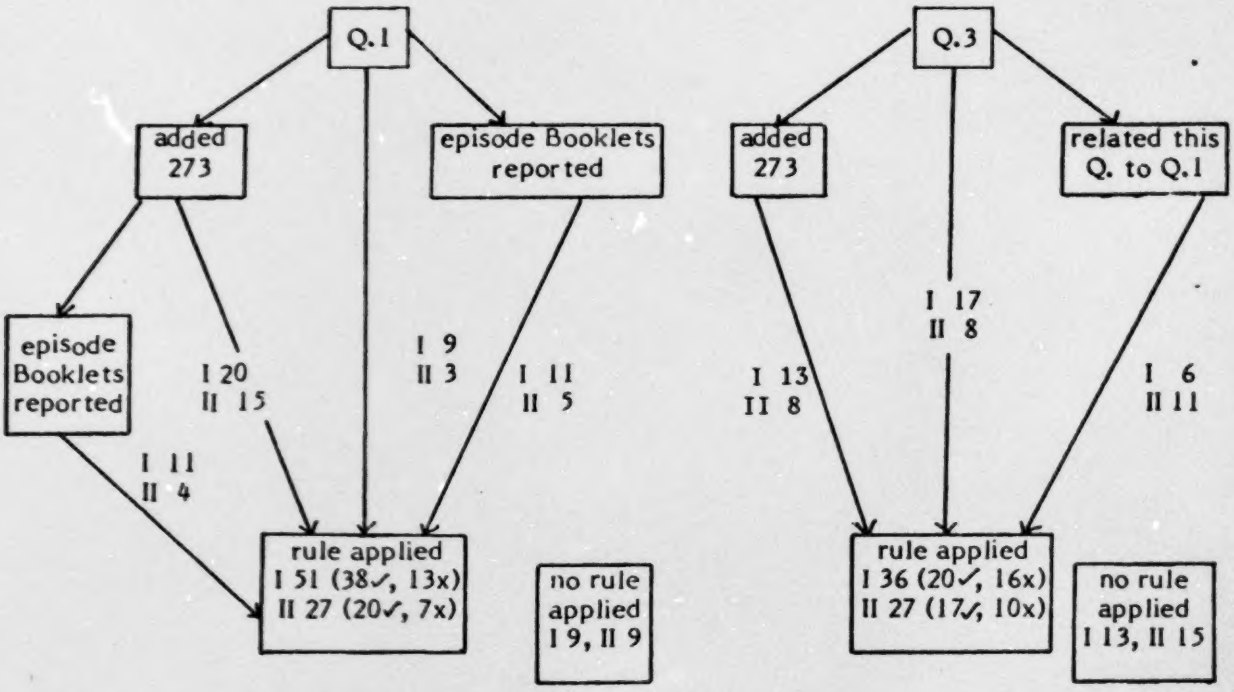

Figure 1: Number of students reporting the main patterns of linking for intellectual skills questions 1 and 3 at retentions I and II

Similarities in the main patterns of linking reported by students across the eight intellectual skill questions were evident. Many students indicated they had no conscious thoughts. For a particular question the number of such responses appears to be related to the difficulty of the question. The links most often reported by students were, an episode relating to the Booklets, an episode relating to the mathematics classes, a search how to do the problem, and relating a particular question to a previous question in the test.

The experience of working with the instructional Booklets apparently resulted in most students storing an episode of this in memory linked to the intellectual skills. Examples of such episodic reports are:

- When I tried to do the answers in the Book I had to keep turning back to the example./ (Q.5)
- I saw myself what I was writing in the class, and tried to look what I was writing in the Books./ (Q.8)
- In other Books they showed us how to do it. They had it set out with arrows pointing how to do it./ (Q.5)

Students, particularly in questions 3, 6, 10, 11, reported linking to a previous question in the Retention Test.

- Realised again, had to do the same again like in the other question - rearrange equation and substitute./ (Q.6)

In questions 5 and 8, the most difficult intellectual skill questions, many students indicated a search for the appropriate intellectual skill.

- Racking my brain trying to work out how we did these questions the last time we did them./... (Q.8)
- ... Trying to remember the process how to do it./... (Q.5)

Images were evoked, particularly in questions 1, 3 and 8. Examples of such reports are:

- Thinking about water in a beaker. That's it. Thermometers -pictures of this./ (Q.1)
- Pictured a mixture of salt and ice and water./ (Q.3)
- Imagining a balloon filled with 1.2 litres of water./ (Q.8)

A number of students for question 3, and many students for question 8, were unable to make a final intellectual skill link at either retentions I or II. At retention II few students recalled any of the questions being in the previous test.

Propositions

The same strategies that were used to present the interview data for the intellectual skill questions were used for the proposition questions.

There were significant differences between the means for propositions 2 (I, II), 13 (I, II) and 14 (I). There are no marked similarities in the patterns of linkings reported across the six proposition questions. Within a particular question there were generally more different patterns of linkings reported than were reported for an intellectual skill question.

There was negligible reference to using the strategy of relating a question to a previous question in the Retention Test. Except for question 9, many students made no final proposition link. Generally more students were unable to provide a written answer to a proposition question and make a final proposition link, than were unable to provide a written answer to an intellectual skill question and make a final intellectual skill link.

In question 9 all students made a final proposition link. This question is the only question set in a 'select one' from the table' format. This raises interesting questions about the relationship between the manner in which a problem is presented and the memory structure links reported overtly by students.

Episodes relating to the Booklets were reported across all proposition questions but minimally in question 14.

- The only thing I could think of was the Booklet - the Law was on the front page./ (Q.2)

- I remembered the little man on the skis in the Book./ I always remember kilopascal because I think of Pascall lollies./ (Q.9)

- I went back to the science room with the Books. Everyone was along the desks, kids in front of us, and someone turned on the tap. I was doing that page (the one with the pressure units on it) when I was squirted./ (Q.9).

- I just remembered it because of the diagrams in the little Booklet. We had two diagrams of little dots spreading through the whole square. Next door the molecules were squashed down./ (Q.13)

A number of the reported episodes have a strong image component.

For question 14 there was negligible reporting of a link to an episode relating to the Booklets. Some students evoked an image of railway lines. Many students reported detailed episodes about railway lines.

- We made a film at Blackburn Station. We had tied someone on the line./ I had to think if they expand in the heat or the cold./

- A picture of when I was boarding a train at Nunawading Station to go into the city. It was a hot day./ Heat expands everything.

- When I was in Form 1 at my old school we were talking about this one day and I thought back to that room where I was and listening to the teacher telling us./

Few links to the science practical experiments were reported except in question 7.

When answering the proposition questions in the Retention Test, students tended to evoke images or link to episodes having a strong image component, search for a proposition, and link to episodes concerning the Booklets. Many students made no final proposition link for particular questions.

DISCUSSION

Students who better retained previously learned propositions and intellectual skills generally reported a greater number of links between and within the four memory structures. The reverse held for one question. A significant negative difference found in question 4 (II) suggests that students presented with a particular type of problem encountered on numerous occasions, tend to answer

somewhat automatically and are likely to report fewer rather than more memory structure links compared with those answering the problem incorrectly. This finding supports research reported by Kruteskii (1976). He claimed that "the curtailment of reasoning depends on the problem's structure and degree of difficulty as well as the extent of training in solving problems of that type" (p.264).

For the intellectual skill questions in the Retention Test the most often reported links were; an episode relating to the Booklets, an episode relating to the mathematics class, a search how to do the problem, and relating a particular question to a previous question in the test. For the proposition questions these were, image formation or an episode with a strong image component, search for a proposition, and an episode relating to the Booklets. The more difficult a question, the more varied the reported linkings between and within the four memory structures tended to be.

Students reported on the aspects of cognitive structure which they used to help solve the problems presented. Links to the instructional procedures and processes were often made. Many referred to episodes relating to the instructional Booklets. Few students overtly linked to episodes formed with the science practical experiments that were part of instruction. Perhaps such episodes were stored in memory but not overtly used.

Several strategies were used to present the interview data from the sample of seventy-eight students. When combined, these enable an economical but detailed reporting of the information from a large number of interviews. It is suggested that these strategies may prove valuable in helping to overcome the difficult task of efficiently and effectively reporting interview data.

Introspection is a valuable technique for investigating retention. It provides

data which cannot be obtained by any other means, and assists in highlighting the aspects of cognitive structure which students reportedly refer to when answering questions relating to intellectual skills and propositions previously learned.

APPENDIX A

RETENTION TEST

Only your answer will be viewed. Setting out not important

1. The temperature of water in a beaker is $47.5^{o}C$. What is this temperature in degrees absolute?

2. What is the name given to the Gas Law which can be represented mathematically as $P_1V_1 = P_2V_2$?

3. When a Celsius thermometer is placed in a mixture of salt, ice and water the thermometer registers $-6.2^{o}C$. What is the temperature of the mixture in degrees absolute?

4. Given that $x = y + z$, calculate the value of 'x' if $y = 76.4$, and $z = 226.8$.

5. In the equation $\frac{ab}{c} = \frac{pq}{r}$, calculate the value of 'b' given that $a = 2.3$, $c = 3.8$, $p = 21.8$, $q = 37$, $r = 8.2$. (Leave your answer in unsimplified form.)

6. The relationship between a, b, s, t is $\frac{a}{b} = \frac{s}{t}$. What is the value of 'a' if $s = 11.8$, $b = 634.7$, $t = 39.5$? (Leave your answer in unsimplified form.)

7. A gas syringe has a certain volume of oxygen gas in it. If the temperature of the gas increases (and the pressure remains the same) what effect would this have on the volume of the gas?

8. A balloon has a volume of 1.2 litres at 2.1 atmosphere pressure and $20^{o}C$. Calculate the volume of the balloon at 1.6 atmosphere pressure and $27^{o}C$. (Leave your answer in unsimplified form.)

9. From the Table, select one unit of pressure.

Table	inch	cubic decimetre	hectare
	litre	kilopascal	

10. What is the value of 'm'. if $m = y + a$ and $y = -67.1$ and $a = 153.0$?

11. If af = kc, calculate the value of 'f' if k = 428.5, c = 7.8, a = 536.8. (Leave your answer in unsimplified form.)

12. At absolute zero temperature all gases are liquified. What is absolute zero temperature in degrees Celsius?

13. What volume is actually occupied by the molecules of a gas (the gas being in a container having a fixed volume) compared with the total volume available?

14. Why are railway tracks laid with small gaps left between the tracks at frequent intervals.?

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